

that I have used as an illustration a series computed by that very machine. * * *."

In the same letter Mr. Babbage refers to the following documents :—

Extract from a letter of Mr. Babbage to Sir H. Davy, 3 July, 1822, printed by order of the House of Commons. No. 370, 1823 :—

"Another machine, whose plans are more advanced than several of those just named, is one for constructing tables which have no order of differences constant (p. 2).

"I should be unwilling to terminate this letter without noticing another class of tables of the greatest importance, almost the whole of which are capable of being calculated by the method of differences. I refer to all astronomical tables for calculating the places of the sun and planets. It is scarcely necessary to observe that the constituent parts of these are of the form $a \sin \theta$." (p. 5.)

He refers also to an extract from the Address of H. T. Colbrooke, Esq., President of the Astronomical Society, on presenting to him the first medal given by the Society, 1824; and to a description of his machine by the late Mr. Baily, published in Schumacher's 'Astronomische Nachrichten,' No. 46, and republished in the 'Philosophical Magazine' for May 1824, p. 355. This last paper describes fully what could be done by the new contrivance.

I have ventured to insert this postscript without consulting my colleagues, as it is desirable not to delay the publication.

G. G. STOKES.

London, Oct. 5, 1855.

"Report made to the President and Council of the Royal Society, of Experiments on the Friction of Discs revolving in Water." By JAMES THOMSON, Esq., C.E., Belfast.

[A Committee of the British Association for the Advancement of Science, consisting of James Thomson, Esq., C.E., and William Fairbairn, Esq., C.E., F.R.S., having been appointed "to make Experiments on the Friction of Discs revolving in water, with especial reference to supplying data wanted in calculations relative to

the action and efficiency of Turbine Water-Wheels in general, and of Centrifugal Pumps; and also to make an experimental investigation relative to the action and efficiency of Centrifugal Pumps in general, and the amount of improvement derivable in them by the employment of an exterior whirlpool;" a sum of £50 from the Government Grant of 1853 was allotted by the Council of the Royal Society in aid of the inquiry. The experiments, as originally contemplated, have been arranged and conducted by Mr. Thomson, and the present Report of his progress is here inserted by order of the President and Council for the information of the Fellows.]

In last year's Report of the Committee it was stated, that an apparatus for making experiments on the friction of discs revolving in water had been constructed, and that experiments had been commenced with it. I have now further to state respecting the experiments for which that apparatus was adapted, that I have since got them completed and carefully arranged for the purpose of obtaining from them laws applicable for practical use.

I now beg to lay before the Royal Society, as a brief statement of the most essential results, the following general equation to show the relation between the velocity of revolution of the disc, the diameter of the disc, and the mechanical work consumed in friction :—

$$z = \frac{y^3 d^5}{90,000},$$

in which d =diameter of the disc in feet,

y =number of revolutions of the disc per minute,

and z =number of foot-pounds of mechanical work consumed per minute.

This equation is based on experiments which range for the most part between the limits $yd=192$ and $yd=518$, and may be used with confidence, as sufficiently correct for most practical purposes, if the product of the number of revolutions per minute and the diameter of the disc in feet be between those limits. It is to be observed that the friction is slightly affected by the width of the water space within the case, and the coefficient 90,000 stated in the formula above is, for simplicity in the present brief report, taken between the coefficients obtained by two sets of experiments with different widths. A full report on the experiments already made,

explaining the manner of conducting them and stating the detailed results, would be rather lengthened, and would require drawings and diagrams, for all of which I have carefully preserved the requisite data; but before proceeding to put these in form suitable to be submitted to the Royal Society, I am desirous of prosecuting the remainder of the very interesting and important experiments which have been entrusted to me,—that portion of the whole, namely, which relates especially to centrifugal pumps. I have also to state, that if my engagements permit, I should be desirous of proceeding with a renewed and more extended set of experiments on the friction of discs, with an apparatus depending on the same leading principle as that which I have already used,—a principle which on trial has been found remarkably well suited for the desired purpose. For the attainment of greater accuracy and of a wider range of the experiments, it seems to me that no better method of procedure could be adopted, than to follow the same leading principles, with an apparatus of rather more refined construction, involving such improvements in details as have been suggested by the experience gained in the course of the experiments already made, and for the sake of greater steadiness of motion, worked by steam power instead of the hand of an operator. Should I have it in my power to conduct this renewed set of experiments, a detailed account of them will be preferable to a detailed account of those already made.

In respect to the experiments on Centrifugal Pumps, I have to say that I have prepared plans for an experimental apparatus on principles which I consider are peculiarly well suited for the attainment of useful and accurate results, and that I intend to proceed with the experiments as soon as my engagements shall permit.

I have further to state, that from the Experimental Fund of £50 granted by the Royal Society, the entire outlay as yet incurred has been £6 5s. 9d, leaving a balance of £43 14s. 3d. for the more extended experiments yet remaining to be made.

JAMES THOMSON.

Belfast, April 13, 1855.